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ECONOMIC VALUE OF THE INTERNATIONAL ICE PATROL

Clark W. Pritchett

U.S. Coast Guard
Research and Development Center
1082 Shennecossett Road
Groton, CT 06340-6096

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G.T. Gunther
Commanding Officer
United States Coast Guard
Research & Development Center
1082 Shennecossett Road
Groton, CT 06340-6096

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16. Abstract

An approach for estimating the economic value of the International Ice Patrol (IIP) to the shipping interests of a country is developed. The ship routing method that uses IIP products is compared with an approach that uses historical information (climatology) about the iceberg limits. The additional cost of transiting using climatology (compared to IIP routing) is the economic value of the International Ice Patrol for one voyage. An example using a typical US containership is developed to estimate the return on investment to the United States of the economic benefit of IIP to United States shipping. The economic value is a measure that can be used to understand how the International Ice Patrol benefits the shipping interests of a nation and to quantify that benefit.

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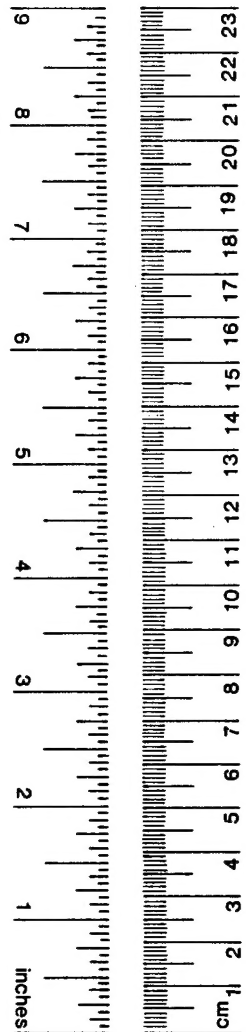
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

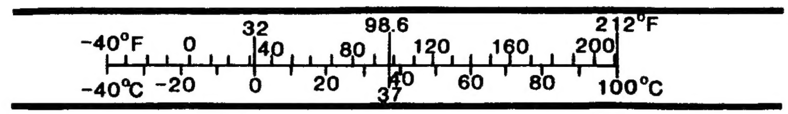
Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (WEIGHT)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (EXACT)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly).



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (WEIGHT)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	0.125	cups	c
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (EXACT)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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EXECUTIVE SUMMARY

An approach for estimating the economic value of the International Ice Patrol (IIP) to the shipping interests of a country is developed. Two different ship routing concepts are analyzed and the additional time to transit around the iceberg region is estimated. The routing method that uses IIP products is compared with an approach that uses historical information (climatology) about the iceberg limits. The cost to transit the additional distance due to the climatology routing is computed based upon the overall ship operating costs. An argument is made that this additional cost is the economic value of the International Ice Patrol for the voyage. The economic value to a nation is the sum of the values for each individual voyage. This approach is shown in an example that uses a typical US containership for the voyage. The example is extended to include an estimate of the return on investment by comparing the United States share of IIP costs to the economic benefit of IIP to United States shipping. This approach is limited by the assumed behavior of a typical mariner, the higher risk that climatology entails and the quality of information that describes the operating cost of the ship. The economic value is a measure that can be used to understand how the International Ice Patrol benefits the shipping interests of a nation and to quantify that benefit.

INTRODUCTION

The RMS Titanic sank in the icy waters off the coast of Newfoundland early in the morning of April 15, 1912, after hitting an iceberg the night before. The tragic loss of over fifteen hundred lives shocked the world in 1912 and is still vividly remembered today in books and movies, and even on Internet home pages[1]. In the aftermath of this unprecedented disaster at sea, thirteen nations involved with shipping in the treacherous North Atlantic came together to prevent a catastrophe like the sinking of the Titanic from ever happening again. Their response was basically very simple but effective. Henceforth, the portion of the transatlantic shipping lanes that were threatened by icebergs would be guarded by observers. They would report sightings of icebergs to mariners who would then take the appropriate actions to avoid the iceberg danger. Thus the concept of the International Ice Patrol (IIP) was born. For the remainder of 1912, two ships of the US Navy were used to guard the ice limits. In 1913, they were replaced by two Revenue Cutters. The first International Conference on Safety of Life at Sea (SOLAS) formally inaugurated the ice patrol services in 1914.

The mission of the International Ice Patrol of the U. S. Coast Guard and its predecessor, the Revenue Cutter Service, has remained essentially unchanged since the original SOLAS conference of 1914. That mission is to determine the limits of all known ice (LAKI) along the southeastern, southern and southwestern edge of the ice region around the Grand Banks of Newfoundland and make that information known to mariners in a timely fashion. The Coast Guard has performed this mission continually, except for the years of the World Wars, since 1913. In 1914 the Coast Guard was formally charged with the management and operation of the ice patrol for the international community. In 1946 cutters were replaced by Coast Guard aircraft with ice observers on board since airplanes have better search capabilities and are less expensive to operate than ships. Since 1979, IIP has used oceanographic drift and deterioration models to more accurately predict the location of the iceberg limits. Beginning in 1983, the AN/APS 135 SLAR (side looking airborne radar) has been carried on Coast Guard Hercules HC-130 aircraft to search for icebergs. The AN/APS 137 FLAR (forward looking airborne radar) was added in 1993 to improve the overall searching capabilities.

The benefits of the ice patrol services continue to be recognized[2] today by the seventeen nations that underwrite the operations of the International Ice Patrol. Everyone agrees that the service is valuable, but the benefits are not measured easily. The direct benefit of course is preventing a collision between a ship and an iceberg. Preventing the loss of life is clearly beneficial but difficult to quantify since the value of a human life is not measured in economic terms (except by lawyers). There have been no ship-iceberg collisions reported outside of the limits of all known ice since the International Ice Patrol has been in existence. Since a ship-iceberg collision is such a rare event, it does not make sense to assign a probability to it because there is not enough data (read ship-iceberg collisions) to make reasonable estimates. Still, ships must travel inside the ice limits to reach certain points in Canada. In 1993 there were three collisions reported between ships and icebergs inside of the ice limits. There was significant vessel damage but no lives were lost. The loss of revenue to the shipping companies during the repair period could have exceeded the cost of repairs, which are always considerable for a ship. It is clear that there are costs associated with hitting an iceberg and benefits to a safe and uneventful transit, but they are not easily quantified. On the other hand, there is an economic benefit of the International Ice Patrol

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[1] One of thirty plus sites is http://www.fireflyproductions.com.titanic/

[2] The Triennial Meeting of SOLAS signatory nations was held in Washington, D.C. on Oct. 4, 1996. Every nation attending affirmed the value of the International Ice Patrol to their mariners.

which can be estimated without any of the attendant difficulties referred to above. Estimating this benefit, or economic value, of the IIP is the subject of this paper.

PROBLEM STATEMENT

Ships normally take a great circle route between their ports of origin and destination to minimize the total distance (and time) that they travel on a voyage. If there are points of land, shallow water, a storm or any other known hazard along the planned route, a longer route, consisting of a series of great circle segments with appropriate way points, is used for the voyage. This is how vessels transiting the North Atlantic during the iceberg season[3] navigate. The shortest route between Europe and landfall of the United States is a great circle route. For approximately half of any given year, icebergs drift south across the shipping lanes and force mariners to take a more southerly route to avoid them. Additional way points are determined from the location of the reported limits of all known ice (LAKI) that IIP provides to the mariners and a safe route is charted. The mariner uses the products (facsimile charts and broadcasts to mariners) of the International Ice Patrol in order to make the voyage as safe as possible by transiting outside of the iceberg limits. [Safe means that there will not be a collision between the ship and an iceberg on the trip.] It follows then that the total distance that a vessel travels is influenced by the ice limits. For vessels traveling in the North Atlantic, the farther south the ice limits are, the farther the vessel must travel to avoid the area with icebergs. For example, the difference between a route that cuts through the iceberg area and one that avoids it can be as great as 340 nautical miles for a vessel traveling from northern Europe to New York. At an average speed of 20 knots, this increased distance would add 17 hours to the voyage.

If IIP services were not available to the mariner, vessels would still need to avoid the areas that contain icebergs but the navigators would lack the precise information about the location of the iceberg limits. It is reasonable to assume that the ship's master would draw upon his past experience with icebergs in a particular geographical area at the same time of year to chart the best course. A mariner with a long history of North Atlantic transits and good record keeping could compile an atlas of the location of all known icebergs, over time, and use that information to help determine the best vessel route by avoiding areas that were known to have had icebergs in the past. Iceberg information from many vessels could be combined with experience and judgment to get an approximation of the ice limits of the recent past. Although possible, this approach does not appear to be plausible at this time based upon the large number of different vessels that transit the North Atlantic and the lack of any central organization for information collection and distribution. Using climatology[4] for vessel routing has been discussed by navigation professionals in the past but has not been used, partly[5] due to the lack of accurate information.

Fortunately the International Ice Patrol has recently compiled statistical information about the ice limits for the last twenty-one years (1975-1995) in a climatological atlas (Ref. 1). It presents the ranges of the ice limits for two week periods from mid-March until the end of July for these twenty-one years on charts (Appendix). The minimum and maximum ice limits for two week periods are presented along with the 25th and 75th percentile and the median limits. This information is available to the public and could be used by the maritime community to route their ships around the climatological limits of all known ice, if the IIP products and services were not available. A prudent mariner could choose a route based upon the southern most climatology limits (extreme) for the two week period that was

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[3] At the extremes, the ice season can run from early February until mid September.

[4] The term climatology will be used to refer to historical iceberg information; data, charts, etc.

[5] Other reasons are discussed in following sections of the paper. One way of looking at climatology for predicting ice limits that the mariner would be using the worst case scenario of the past to make decisions about the present.

appropriate for the date of the transit. By routing the ship outside of the historical iceberg region, the mariner would hope to achieve the same level of service, i.e. no ship-iceberg collisions, that is presently provided by using the IIP products. The assumption that both routes are equally safe is optimistic.

Although using historical ice limits to represent the location of icebergs in real time is a seductive concept, there are significant problems with it. The climatological atlas is based upon twenty-one consecutive years of data, not a random sample from a temporal distribution. Twenty-one years is a very small slice of geological time since icebergs were formed by glaciers over thousands of years. There is an abundance of evidence in recent years that there is global warming but the effect upon iceberg calving and melting is not understood very well at this time. Ice seasons of the future may be more (or less) intense than any in the climatological atlas. The extreme limits of iceberg travel in the future may be outside of the observed limits of the past so there is risk in using historical information to predict the future location of icebergs. If the true limits are inside the historical limits, the ship will needlessly travel some additional distance which will add time and cost to the voyage. If the true limits are outside of the climatology limits on a particular day, the mariner will save time on the transit since he will travel a shorter distance, but there is an increased risk of a collision since icebergs will be in the waters that the mariner is transiting. It should be noted that the method that IIP uses to predict the location of icebergs is also not without some risk. Although it is difficult to quantify, the accumulated risk associated with sampling (airplane flights) and computer drift model prediction error, is much lower than using only historical information to define the ice limits.

There are other potential limitations to using climatology for vessel routing. We have assumed that the prudent mariner will follow the historical extreme location of the ice limits. A more conservative mariner may even add a buffer to the extreme limits of the past. On the other hand some mariners, based upon their experience or company policy, may choose to use ice limits, such as the median, that are less extreme which will add risk to the voyage. It should be recognized that the assumption of equally safe and efficient routes using either IIP products or climatology is not necessarily true. There have been no ship-iceberg collisions reported outside of the LAKI since IIP has been in operation but there is increased risk from using climatology. Also, the climatology ship route is potentially different than the IIP route.

The alternative ship routing concepts described above can be summarized as follows. The difference between the International Ice Patrol routing and a great circle route is the additional distance that the mariner must travel to avoid icebergs. This distance must be added to the planned great circle route to avoid the iceberg threat and it adds additional time (and cost) to the voyage. The difference between the climatology routing and the International Ice Patrol routing is the additional distance that the mariner must travel to reduce the chance of encountering an iceberg, lacking the information that IIP provides. The mariner may still encounter an iceberg if the climatology limit is not as extreme as the true iceberg limit some time in the future and this will add risk to the trip. If the true limit is less than the climatology limit, the mariner will travel an unnecessary additional distance to avoid iceberg danger that does not exist. Lacking real time information, the mariner would be ignorant of the location of the true ice limits. This additional distance will add to the time of the voyage as shown in the following example. If a mariner had used climatology instead of the IIP products on July 15, 1996, he would have traveled an additional 332 nautical miles on a trip from northern Europe to New York. This distance was determined by taking the difference between the routes that used the most southerly way points from the IIP charts and the historical, i.e. climatology information. We can attribute the difference in distance between the great circle and IIP routes as due to icebergs and the difference between the IIP and climatology routes as due to ignorance of the true iceberg limits.

ECONOMIC APPROACH

In order to estimate the economic value of the International Ice Patrol we need to make some assumptions. First we will assume that no International Ice Patrol services will be available to the mariner and that the mariner still wants to pass safely through the region with icebergs. Next we need to address how the prudent mariner would navigate without the aid of IIP's services. We will assume that the mariner will follow the extreme limits of climatology as way points for routing around the iceberg region. The last assumption is that the climatology routing is equally as safe as using the IIP services. For the reasons described above, we know that this is a weak assumption but it is necessary to develop the economic value of the International Ice Patrol. We will revisit these assumptions later.

The mariner can presumably achieve the same level of safety, i.e. no ship-iceberg collisions, by using climatology (historical information) instead of the products of IIP to route the vessel beyond the iceberg danger. On any given day the historical limits cannot be more accurate than the IIP limits since the IIP limits are the "ground truth" for that day. With either method there will be an additional distance to travel to avoid the icebergs in the proximity of the shipping lanes, but as we will see, they can be significantly different. If the safety/performance is the same for routing the vessel using climatology or IIP's products, then the difference between the two methods is strictly the difference in the distance and time of the transits. The effect of this difference to the mariner is the cost to travel the additional distance necessary to transit the region using the climatological ice limits vice the IIP ice limits. The cost can be determined by multiplying the difference in time between the climatology route and the IIP route, by a representative hourly operating cost for the vessel. This would be the additional cost to the mariner of avoiding the icebergs in the shipping lanes by using climatology instead of the IIP products. This difference can be described as the cost of being ignorant of the accurate location of the iceberg limits.

We see that the additional distance that the ship travels comes from taking the differences between total distances of the two ship routes. The additional time to cover that distance can be computed easily by dividing the additional distance by the ship speed. The economic effect of this additional time can be expressed as an additional cost of the voyage by multiplying the additional transit time by the representative hourly cost for the vessel. So the effect of increased transit distance due to the ignorance of the location of the ice limits is monetary, in whatever units (DM, $, SF, etc.) are appropriate to the shipper. We always hear that time is money, and time is money in the shipping business. More trips per year mean more revenue. Delays mean higher costs. Clearly there is an economic value to minimizing the distance, and hence the time, that a vessel travels during a voyage. We can compute the cost of the additional time the vessel must remain at sea if we know the representative operating costs.

There are direct and indirect costs incurred by a vessel at sea. It is easy to understand direct costs. The wages of the crew must be paid for the time on board, fuel and stores are consumed and more maintenance is required when the machinery operates for more time. There are capital costs to consider over the life of the vessel as well. The debt must be serviced and the ship loses value (depreciates) over time. A cost that is potentially larger than any mentioned so far is the opportunity cost. The added times of individual trips over the years to transit the greater distances around the climatology limits by a vessel can be accumulated. They may well be considerable enough over a ten year period for a vessel to be able to make additional revenue producing voyages. These indirect costs and missed opportunities, although not as obvious, are also very real and must be borne by the vessel's

owners in the long term. The direct and indirect costs are aggregated[6] into a total hourly operating cost that is used to determine the economic cost of the additional transit time.

The economic argument for the value of the International Ice Patrol can be summarized as follows. If the mariner wants to achieve the same perceived level of service as IIP is now providing, he could follow the climatology routing. If he does, he will incur significant additional costs. The shipper should be willing to pay an amount up to, but not exceeding, this additional cost for an equivalent alternative route (i.e. one that gives no ship-iceberg collisions) to the climatology routing. Since routes generated by using IIP products give at least this level of service[7] today, the shipper should be willing to pay up to this additional cost (for climatology routing) for the IIP service. This then is the economic value of IIP to the shipper for one transit through the ice region. Expressed another way, the economic value of the International Ice Patrol to the shipper is positive if the cost of routing the ship using IIP services and products is less than the cost of the additional transit time using climatology.

AN EXAMPLE

The procedure to determine the economic value of the International Ice Patrol is easier to understand with an example. The vessel selected was a typical US containership that uses the North Atlantic trade routes. Vessel costs were estimated by using information from the U. S. Maritime Administration (Ref. 2). Information from climatology (Ref. 1) and actual IIP facsimile charts from 1996 were used as inputs to a navigation program to determine the transit distances from northern Europe to New York for the containership. Then the difference in transit distances and equivalent times and costs were determined to estimate the economic value of the IIP for one transit of the containership.

<u>Typical US Container Ship</u>

Cargo Capacity - 32,500 Tons   Transit Speed - 20 Knots
Representative Cost - ~$1,000 per Hour

The containership costs actually summed to $1041 an hour but we will use $1000 since it is much easier to understand the calculations that follow. The southern limits of all known ice (LAKI) from the International Ice Patrol facsimile charts of June 30, 1996 and July 15, 1996 and from the climatology for the same dates (Appendix), were used as way points for the voyage. On July 15, 1996, the difference between the total distance of the ship routes using climatology and IIP's facsimile chart, would have been 332 miles. It was not a heavy ice season in 1996 so the ice had receded significantly by July 15. The historical information showed that in one of the past twenty-one years, the ice limits had been much farther south during the same two week period. If the mariner was not aware of the true (IIP) limits, he would have used the climatology ice limits and transited the greater distance. Using the June 30 & July 15, 1996 ice limits from IIP along with the climatology for these two dates and the $1,000 per hour cost of the containership, we get the results below.

<u>Additional Transit Distance, Time & Cost of Climatology Routing Compared to IIP Routing</u>

Date	Additional Distance	Additional Time	Additional Cost
June 30, 1996	160 Naut. Mi.	8 Hours	$8,000
July 15, 1996	332 Naut. Mi.	16.6 Hours	$16,600

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6 The method of assigning fixed costs (such as interest on a loan) to the variable cost (hourly rate) is usually subject to interpretation by a professional cost analyst.

7 The risk associated with the IIP level of service is less than climatology.

The difference between the shortest route around the ice, i.e. using the IIP Ice Bulletins, and the route based on history, i.e. climatology, gives 160 nautical miles on June 30 and 332 nautical miles on July 15. Dividing these distances by the average ship speed of 20 knots, gives the additional times of the transits. Now multiplying these times by the representative hourly cost of operating the ship, $1,000 per hour, yields the additional costs of the transits on these two days, $8,000 and $16,600. These would be the costs for the containership to travel the additional distance to avoid the ice region on these two dates with the same perceived level of safety as the IIP products provide. Data for a U. S. flag breakbulk carrier (from US Maritime Administration) show the total hourly operating cost to be in the range of $500 an hour. If a sixteen knot bulk carrier had to travel an additional 200 nautical miles to avoid the climatological iceberg limits, the increased cost would be $6,250. The majority of the tonnage is shipped by containership but significant amounts of bulk products and oil are also part of the mix. We will continue to use the containership in the example that follows since the concept is the same for every ship type.

These costs are an estimate of the economic value of the IIP for one transit of a typical US containership through the ice region on these two dates. The economic value is a function of the operating cost of each vessel type (tanker, etc.), the date of the transit, the ports of origin and destination of the vessel and ship speed. To determine the aggregated value of the IIP to a nation, the economic value of each transit for every vessel would have to be summed since the economic value of each transit may be different. Aggregating the economic value for a nation is beyond the scope of this paper but a coarse estimate can be made using the economic value from the containership example.

Recently, all aspects of cost and performance of the International Ice Patrol have been analyzed (Ref. 3) in detail. Costs include searching for icebergs with aircraft, predicting the location of an iceberg using computer drift models and staffing the IIP operations center. These activities support the production of facsimile charts, notices to mariners, etc., that provide the maritime community with the information that they use to route their ships around the iceberg danger. IIP costs are funded on a reimbursable[8] basis by the SOLAS signatory nations. In 1994 the total cost of operating the IIP was approximately $4,275,634 (Ref. 4). The latest[9] available information for tonnage shipped is for the year 1992. Averaging the data for 1991 and 1992, shows that the United States shipped 12,406,124 tons per year during the ice season. This is approximately 15.13% of the tonnage shipped by SOLAS signatory nations. Based upon the SOLAS reimbursement agreement and the latest available data, the United States share of the cost to support the International Ice Patrol in 1994 should be $646,821.

We will use the above tonnage and cost estimates in the example that follows to estimate the aggregate economic value of the IIP to the shipping interests of the United States. For the purposes of this example, assume that all of the tonnage that is shipped by US flag carriers is on containerships. Then we can approximate the number of voyages by dividing the total tonnage shipped by the average containership tonnage. If we use the model of the economic value of IIP for one voyage and multiply it by the number of voyages, we get the estimated economic value of the International Ice Patrol to United States shipping. Since voyages will be spread over the ice season, typically from March to August, the economic value for each trip will be different. This can be addressed by assuming a distribution of

[8] The International Ice Patrol tracks costs associated with airplane hours, personnel, computer models, etc. to perform the mission. The SOLAS signatories are responsible for a share of the costs based upon their percentage of the total tonnage shipped through the region during the ice season which is defined to be from February 15 to July 1.

[9] Presently there is a three year lag between the time a vessel transits the ice region when the flag country receives a bill for their share of the IIP services.

transit distances to average the economic values of the individual trips. A return on investment can be estimated by dividing the economic value of the IIP to the United States by the US share of the IIP costs. An example of these computations follow.

Developing Components for Economic Model

Typical US Container Ship

Cargo Capacity - 32,500 Tons Transit Speed - 20 Knots
Representative Cost - ~$1,000 per Hour

Distribution of Additional Transit Distances over the Ice Season

Additional Distance (NM)	0	50	100	150	200	250	300	350	400	Sum
Fraction of Transits (#)	0.02	0.05	0.16	0.21	0.25	0.18	0.10	0.02	0.01	1.00

Additional Distance (Naut. Miles) to Transit (Average from Distribution) = 186

Average Tonnage Shipped During Ice Season (based on 1991 & 1992) = 12,406,124

Equivalent Number of Voyages (Tonnage divided by 32,500 Tons) = 382

Economic Value of One Voyage {(186 Naut. Mi. / 20 Kts.)*($1,000/Hr)} = ~$9,300

Total Cost to Operate International Ice Patrol in 1994 = $4,275,634.

United States Proportion of Total Tonnage (based on 1991 & 1992) = 0.15128

United States Share of 1994 IIP Costs (Total Cost X Proportion) = $646,821

Economic Value of IIP to United States Shipping

382 Voyages X $9,300 per Voyage = $3,552,600 (Economic Value)

Return on Investment (Economic Value divided by US IIP Share) = 5.49

We see that the economic value of the IIP to the United States is in the order of three million dollars and the return on investment is approximately five times the contribution of the United States to the cost of the operation of the International Ice Patrol. In principle, this concept can be extended to determine the economic value of the IIP to the international shipping community. As we have seen, the economic value of a voyage depends upon a number of particular parameters such as the ship route, time of year and vessel operating cost. The economic value of the International Ice Patrol to any nation can be determined by summing the economic values of all of the individual trips for every vessel of that nation. The total economic value could then be used in other analyses such as the return on investment and cost benefit tradeoffs.

Since several significant assumptions were made there is uncertainty in the numbers behind the computation of the economic value. A US containership was used to ship all United States tonnage for a year. Opportunity costs were not included which would add to the total cost for each hour of operation. One distance was used to represent all vessel transits through the ice region. Is this an unrealistic example? Yes, but it illustrates the concept of

how the economic value of the International Ice Patrol can be estimated. Even if this result is 100% higher than the actual value, the return on investment and economic benefit to the United States shipping community are clearly still positive.

LIMITATIONS

Several assumptions were made to develop the economic value of the International Ice Patrol. A most significant one was that routing using the IIP ice limits and climatology will both produce the same level of safety for the mariner. When risk increases for climatology, i.e. the vessel travels inside the true ice limits, then transit costs decrease. When risk decreases for climatology, i.e. the ship travels outside the true ice limits, then transit costs increases. IIP routing appears to be the best mix of risk and cost. Vessels don't normally go into the region that is reported to contain icebergs nor do they travel much farther south than the reported ice limits. Therefore, climatology is not as good an alternative as using the IIP products. So, if both methods cost the same, the IIP routing would be preferred. It was also assumed that the prudent mariner will follow climatology. Some probably will and others may be more or less conservative in their choice of routes. Then the cost-risk tradeoff would have to analyzed on a case by case basis. Climatology based on twenty-one years is a questionable measure of the true distribution of iceberg drift. The variability of the number of icebergs that have been seen each season and their drift patterns leads one to suspect that the iceberg system and attendant climatology will change in some way over time. There is no way to predict the geological future or whether the existing climatology will predict the future extremes of iceberg drift so there is an unknown risk in using climatology for ship routing.

Another area that is open to question concerns ship operating costs. The cost of climatology routing to the shipper depends upon the normal trade route and the vessel particulars. The ports of origin and destination, the vessel's nationality, age, size, crew, personnel policy, speed and even the type of financing, all have an effect upon the total hourly operating cost. Opportunity costs need to be considered in any long-term analysis. They are a function of the rates charged by shipping companies. True costs are only known by the shipping companies and for competitive reasons, they are proprietary. Costs are important because when total ship costs increases the economic value of IIP increases, and when they decrease, the economic value of IIP decreases. If vessel operating costs are high, traveling additional distance is expensive and the IIP routing is preferable. If vessel costs are very low, then the mariner can afford to take a more southerly route to reduce the iceberg danger. In this very competitive world, the first alternative is more likely.

In order to determine the economic value for one transit, all of the factors for each ship transit would have to be considered. To determine the total economic value to a nation, detailed computations with appropriate combinations of shipping routes, ship types, operating costs, ice season intensity, etc. would all have to be considered. To assess the value to the entire maritime community, the economic value of the International Ice Patrol to the shippers of each nation would be aggregated. This is a difficult task considering all of the required information.

CONCLUSIONS

An approach to estimate the economic value of the International Ice Patrol has been developed. An example showed how the economic value of a single voyage was computed and how the results could be used to estimate the economic value to a nation. Based on a reasonable set of assumptions, the economic value of the International Ice Patrol to the United States was shown to significantly exceed the cost of providing the service. This approach could be used to quantify (as well as understand) the value of the International Ice Patrol to the world shipping community. Although technically feasible, a lot of detailed

information is required to produce accurate estimates. This approach may also be applicable to assess the economic value of other Coast Guard services. By structuring the problem so different alternatives have essentially the same benefit, the analysis is reduced to one of economics. Although an economic analysis may not be easy, it is preferred to a cost-benefit analysis where not only do benefits have to be determined but they have to be analyzed along with costs to reach useful conclusions.

REFERENCES

1. International Ice Patrol Iceberg Limits Climatology (1975-1995) International Ice Patrol Technical Report 95-03.

2. Cost information on American flag vessels from U. S. Maritime Administration (Provided by Mr. Tom Olsen of MARAD).

3. Cost and Operational Effectiveness Analysis for Selected International Ice Patrol Mission Alternatives: Armacost, Dr. Robert L.; Final Report (CG-D-19-95).

4. Cost Development for USCG IIP Activities; Armacost, Dr. Robert L.; Annex D of Cost and Operational Effectiveness Analysis for Selected International Ice Patrol Mission Alternatives (CG-D-23-95).

5. Mission Analysis Support for USCG International Ice Patrol (Summary Report): Pritchett, Clark W. and Armacost, Dr. Robert L. (CG-D-01-96).

6. Lloyd's Shipping Economist; Vol. 18, No. 3, March 1996.

7. International Ice Patrol Public Information Brochure

APPENDIX: Charts of Iceberg Region

This appendix contains figures for the Limits of All Known Ice (LAKI) for June 30, 1996 and July 15, 1996 taken from Reference 1 ["International Ice Patrol Iceberg Limits Climatology (1975-1995)"] and the International Ice Patrol facsimile charts for these same two days. A great circle route and routes based on climatology and the products of the International Ice Patrol are plotted on each of the charts.

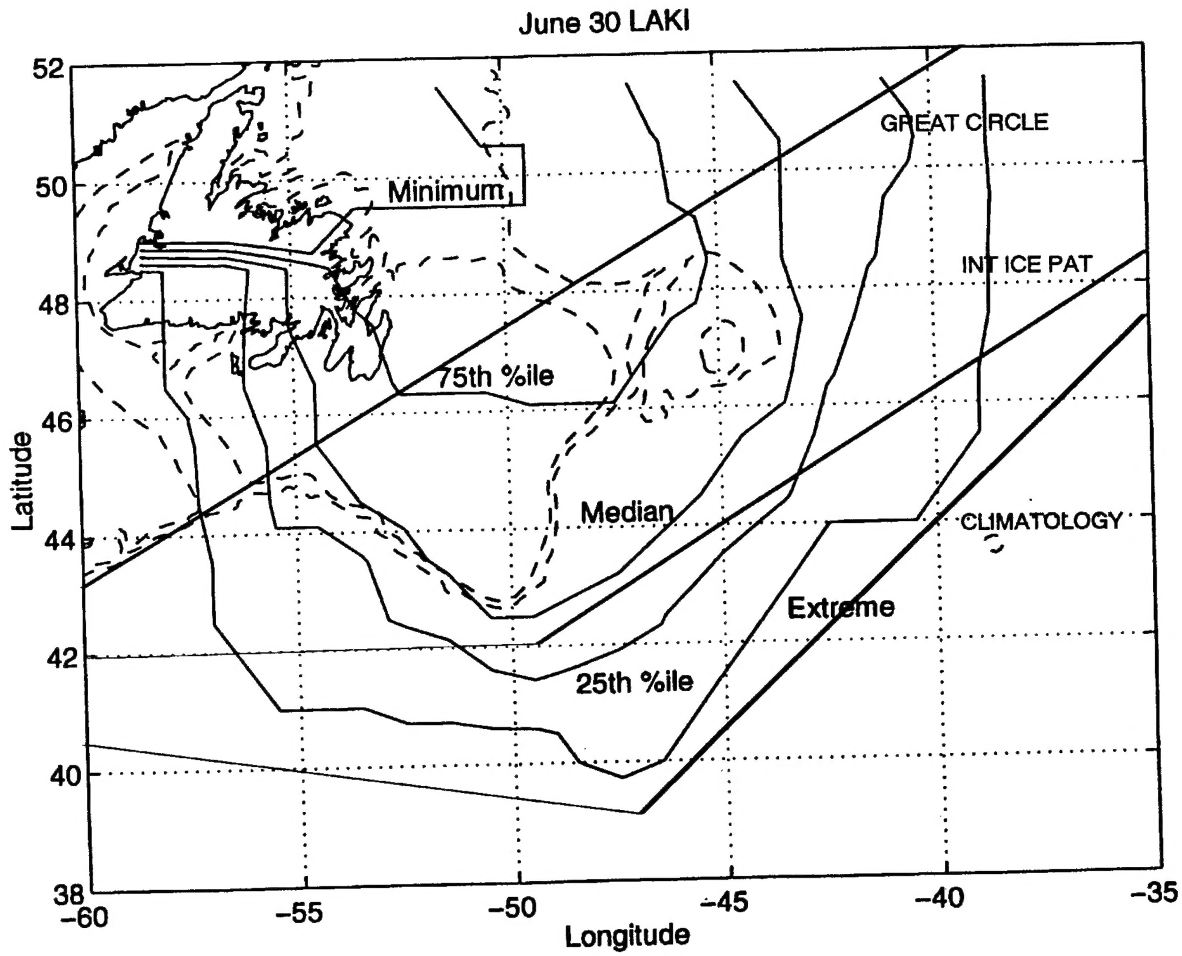


Figure 8. June 30 climatological Limits of All Known Ice (LAKI) based records of the LAKI from 1975-1995.

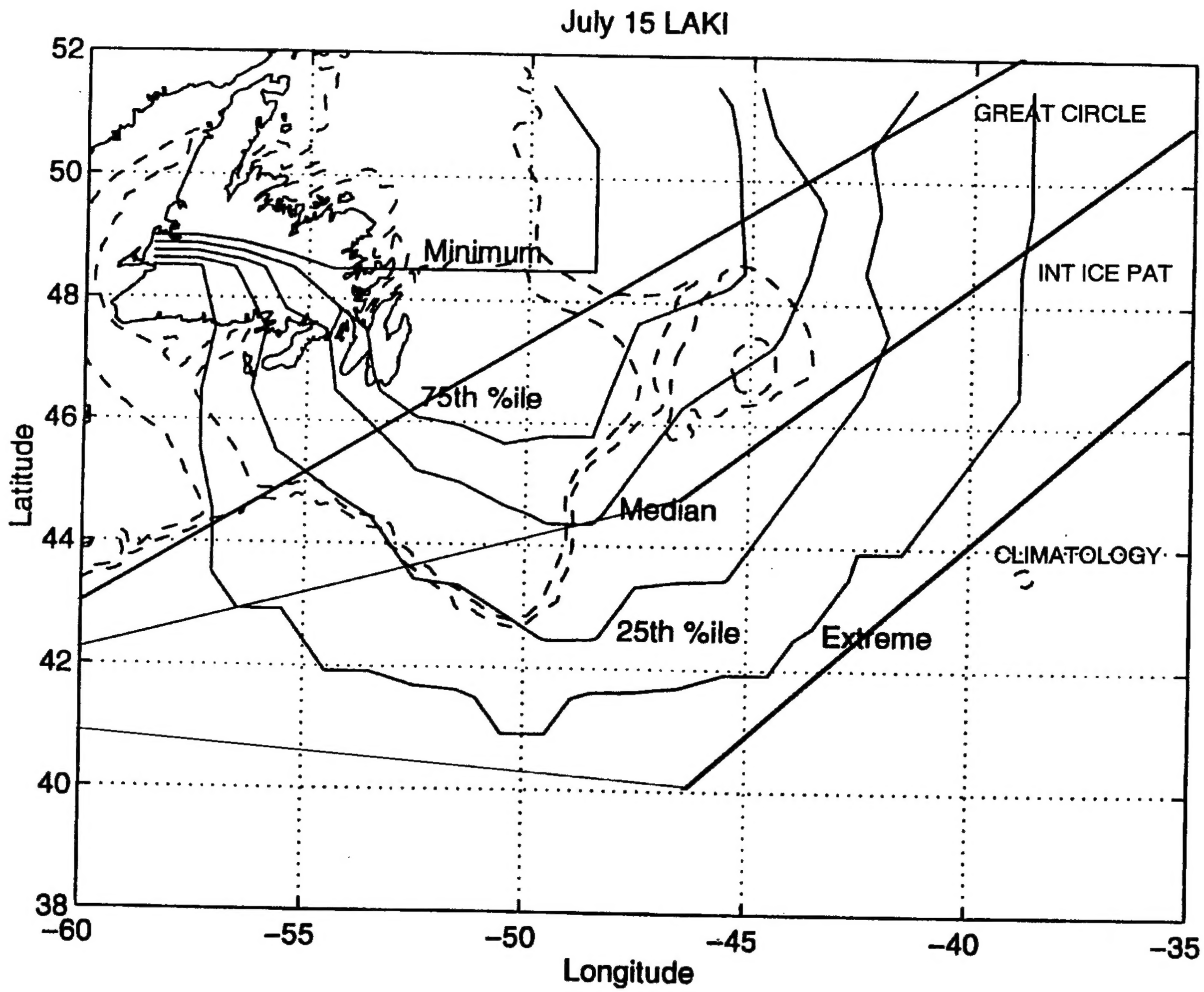
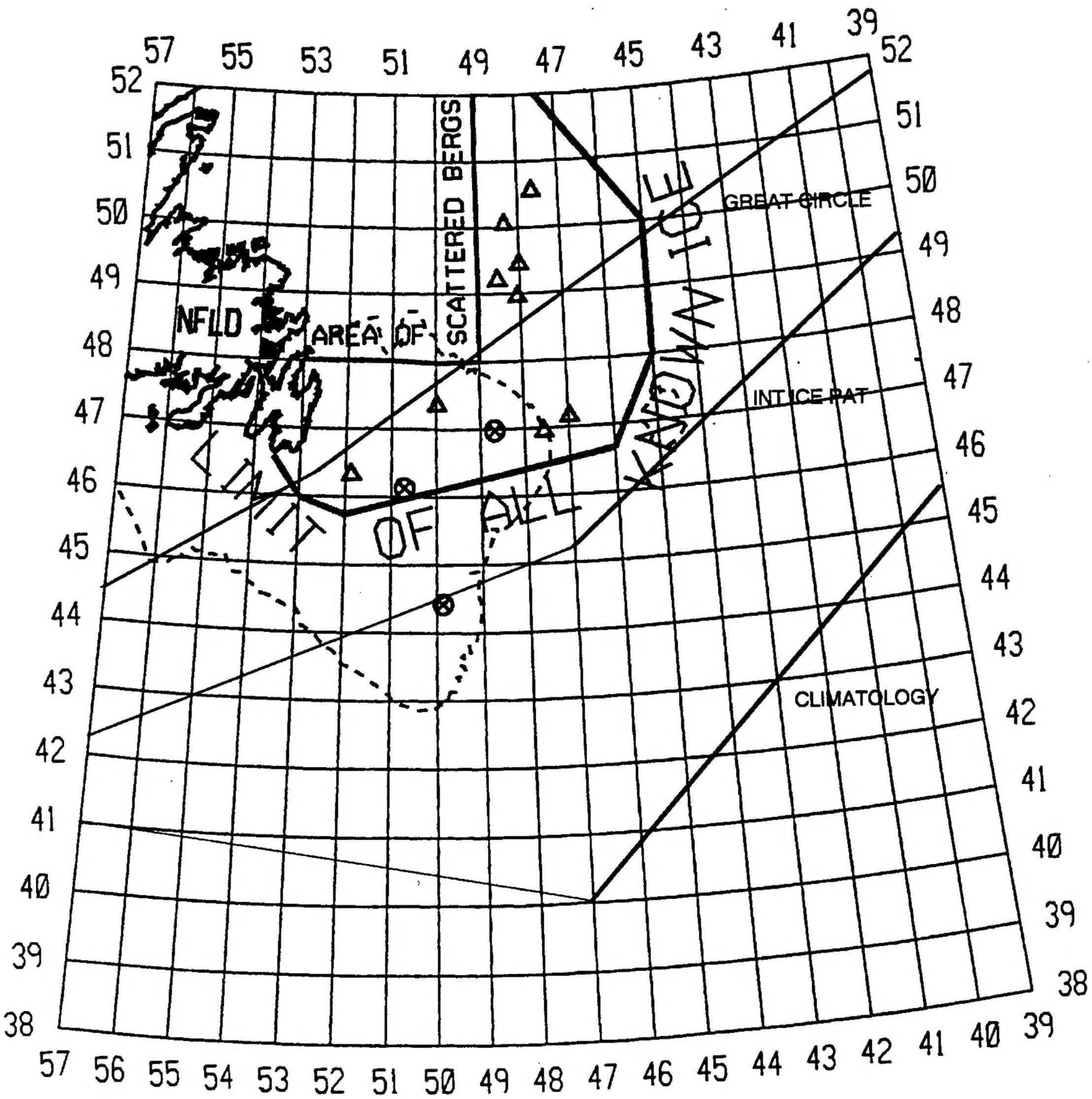


Figure 9. July 15 climatological Limits of All Known Ice (LAKI) based records of the LAKI from 1975-1995.



FOR 1200 GMT 15 JUL 96
BASED ON RECENTLY REPORTED
AND FORECAST CONDITIONS

LEGEND
- △ BERG
- ▭ GROWLER
- ⊗ RADAR TARGET/CONTACT

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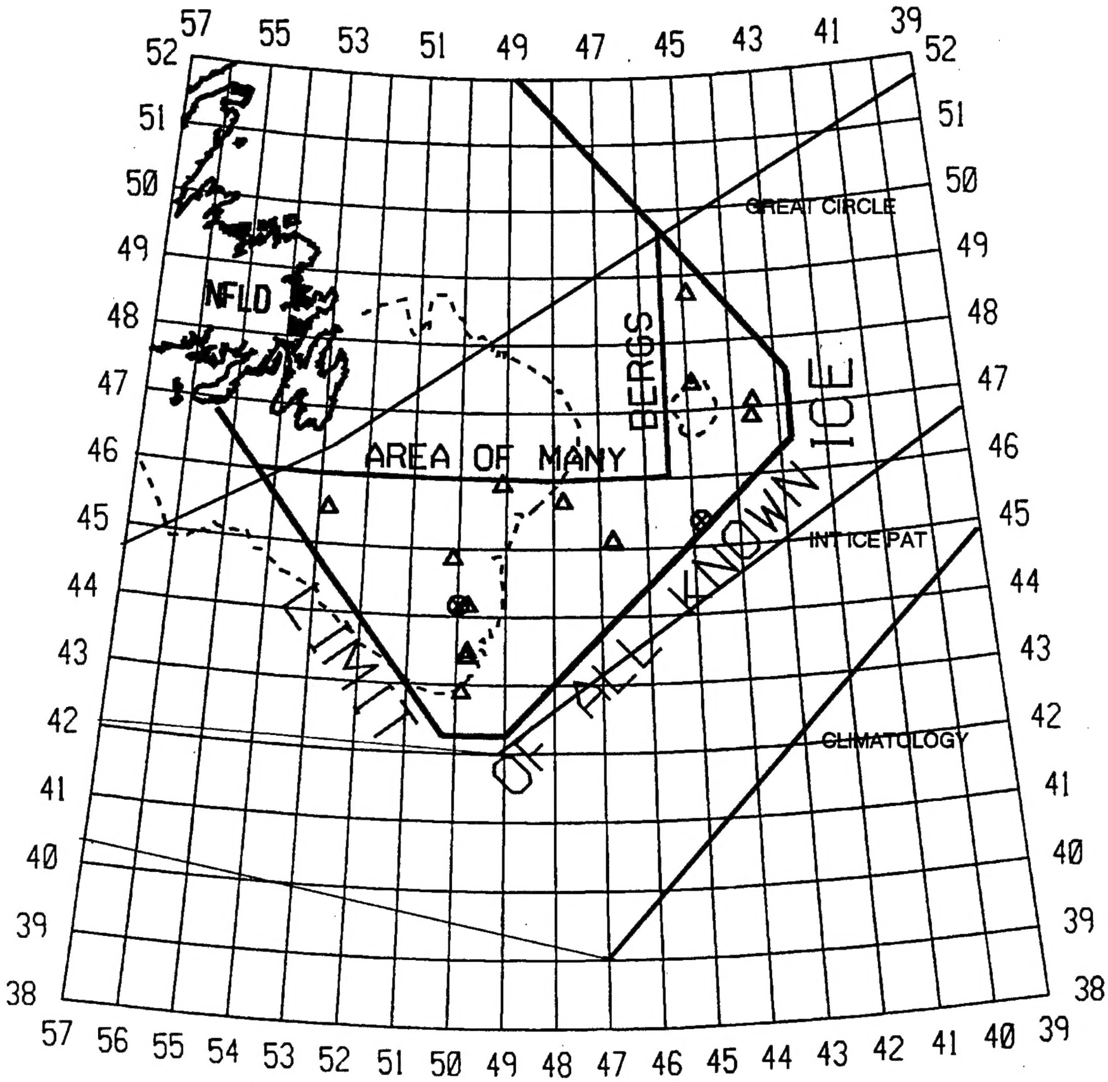

LEGEND
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⏢ **GROWLER**
⊗ **RADAR TARGET/CONTACT**

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